

WATER QUALITY EVOLUTION

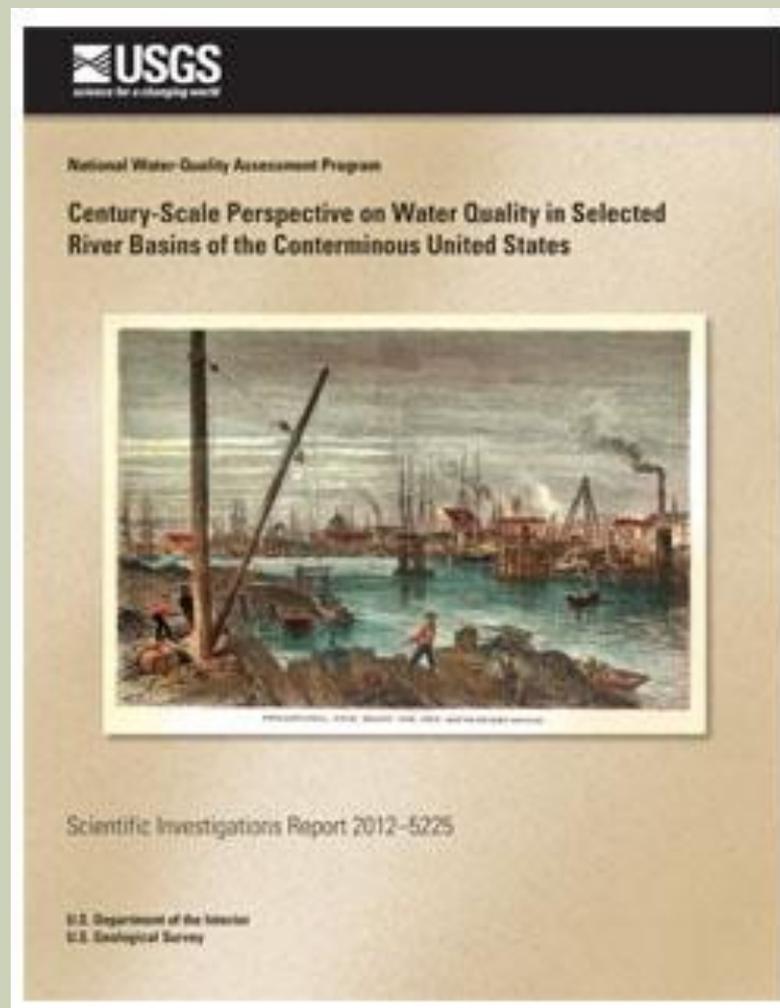
FROM INDUSTRIALIZATION TO THE AGE OF THE INTERNET

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ACKNOWLEDGEMENTS

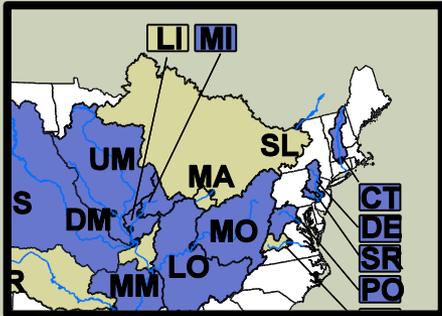
- USGS NAWQA Century of Trends (2009 – 2013)
- USGS NAWQA Cycle III Surface water trends team (2013-present)

- Valerie Kelly
- Whitney Broussard
- Thor Smith
- Charlie Crawford
- Donna Myers
- Lori Sprague





20th Century evolution of water quality



Nitrate concentrations in US rivers remain elevated following historical increases.



Schuylkill River, Philadelphia PA, 1868

20th Century Evolution of Water Quality

THE ROOTS OF WATER QUALITY PROBLEMS IN THE US

- First public waterworks built in 1802.
 - 136 public water utilities by 1860.
 - 600 by 1880.
- Water availability results in increased water usage.
- Beginnings of widespread water quality degradation problems.
- Informal systems were quickly overwhelmed.
- Sewage systems were meant to transport wastewater into nearby waterbodies.
- Blamed for a series of water-borne disease outbreaks in late 19th / early 20th century.



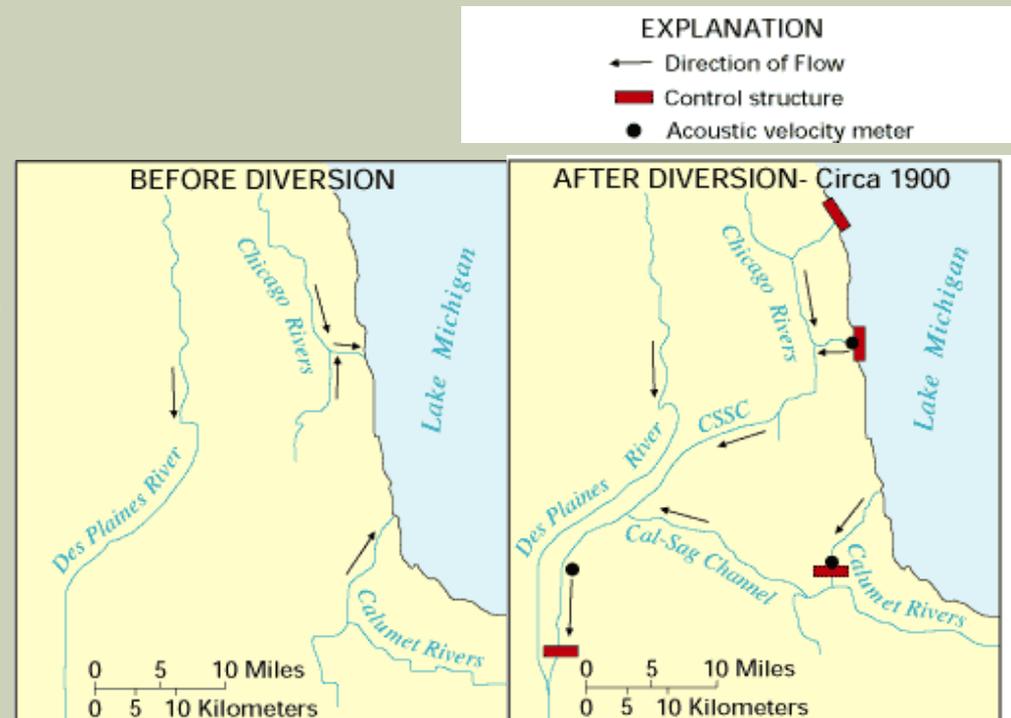
MAJOR ERAS IN WATER QUALITY HISTORY IN THE U.S.

Beginnings of water quality problems	(1870-1900)
Water sanitation era	(1900-1935)
The new pollution emerges	(1935-1948)
Era of growth	(1948-1972)
Clean Water Act	(1972-1987)
Problems and progress	(1987-present)

EARLY RESPONSES TO WATER QUALITY DEGRADATION: CHICAGO RIVER

Chicago Sanitary and Ship Canal

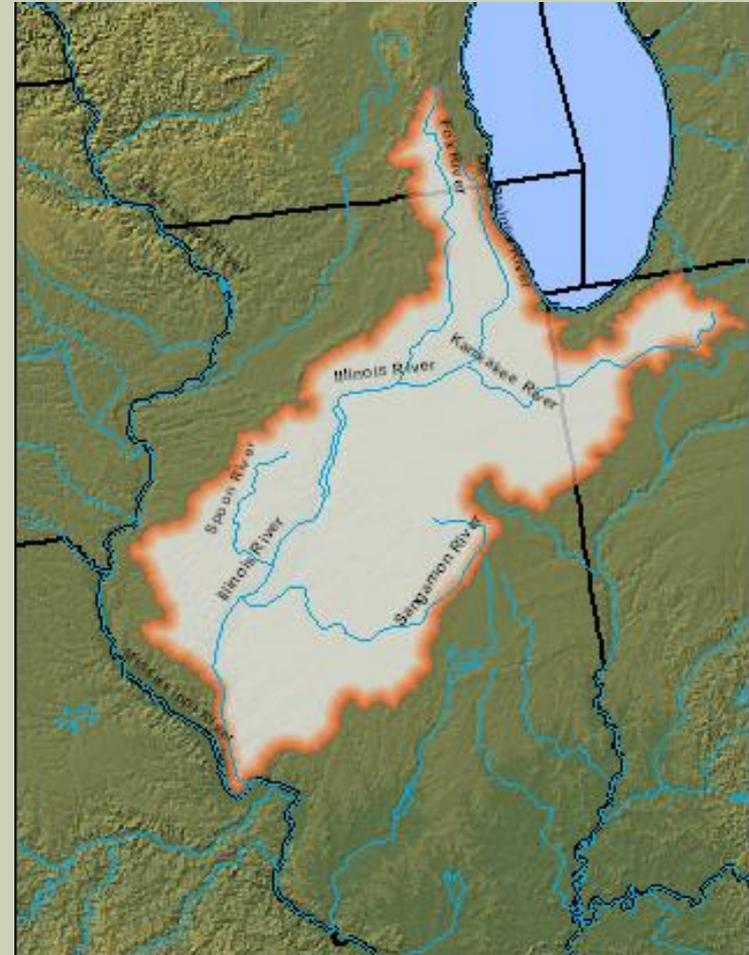
- Repeated cholera / typhoid fever outbreaks in late 19th Century.
- Linked to contamination of Chicago source water (Lake Michigan).
- Chicago River carried wastewater into the Lake.
- River diverted into Des Plaines River
Des Plaines → Illinois → Mississippi
- Wastewater diluted with Lake Michigan water.



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EARLY RESPONSES TO WATER QUALITY DEGRADATION

Federal Government stayed out of it

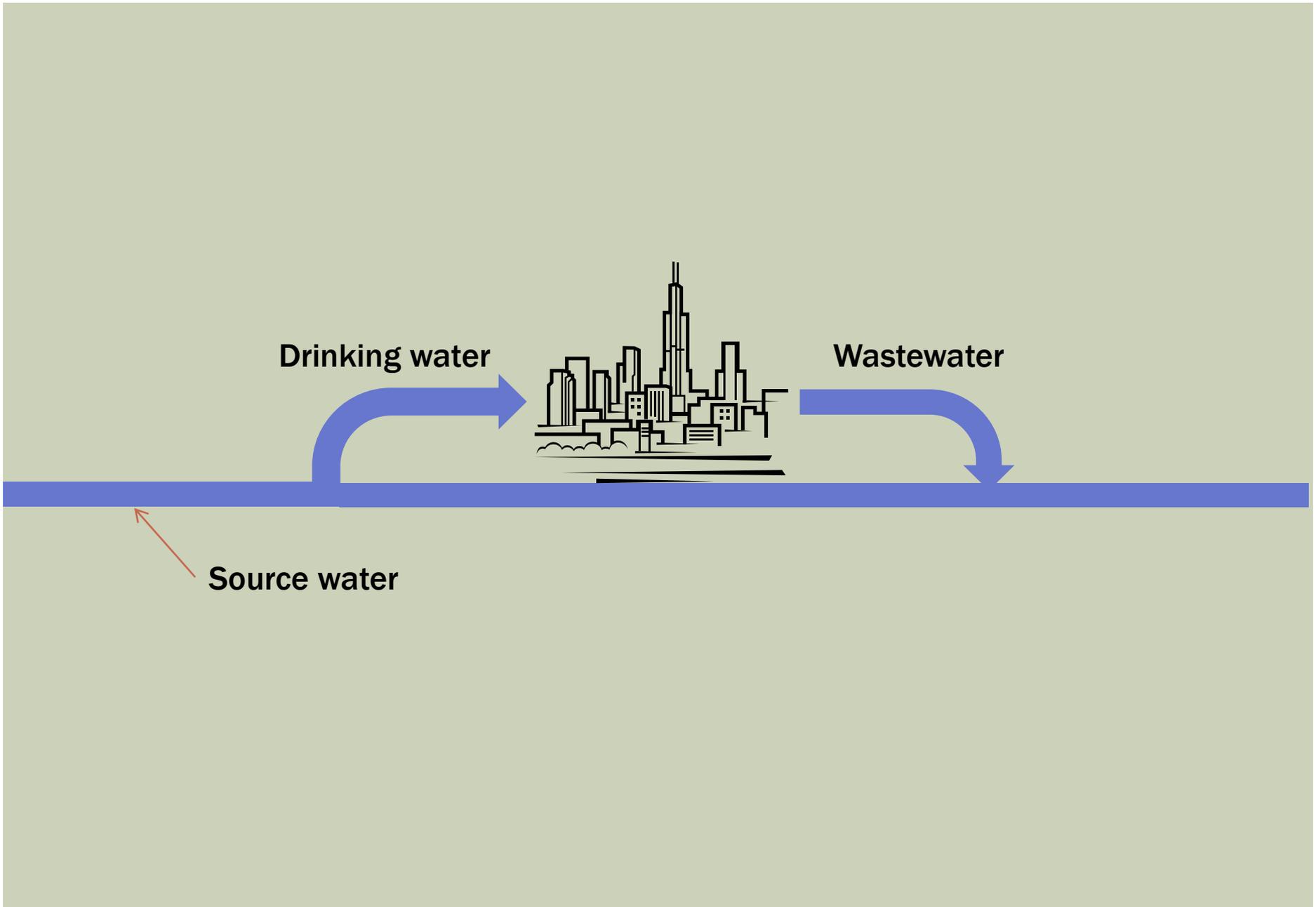
- Navigation protection was the priority.

Many state governments formed Public Health Boards

- Intended to induce better wastewater management.
- In practice, very little was done to treat wastewater.
- Focus on drinking water treatment to combat water-borne illness.

Pittsburgh, PA circa 1900





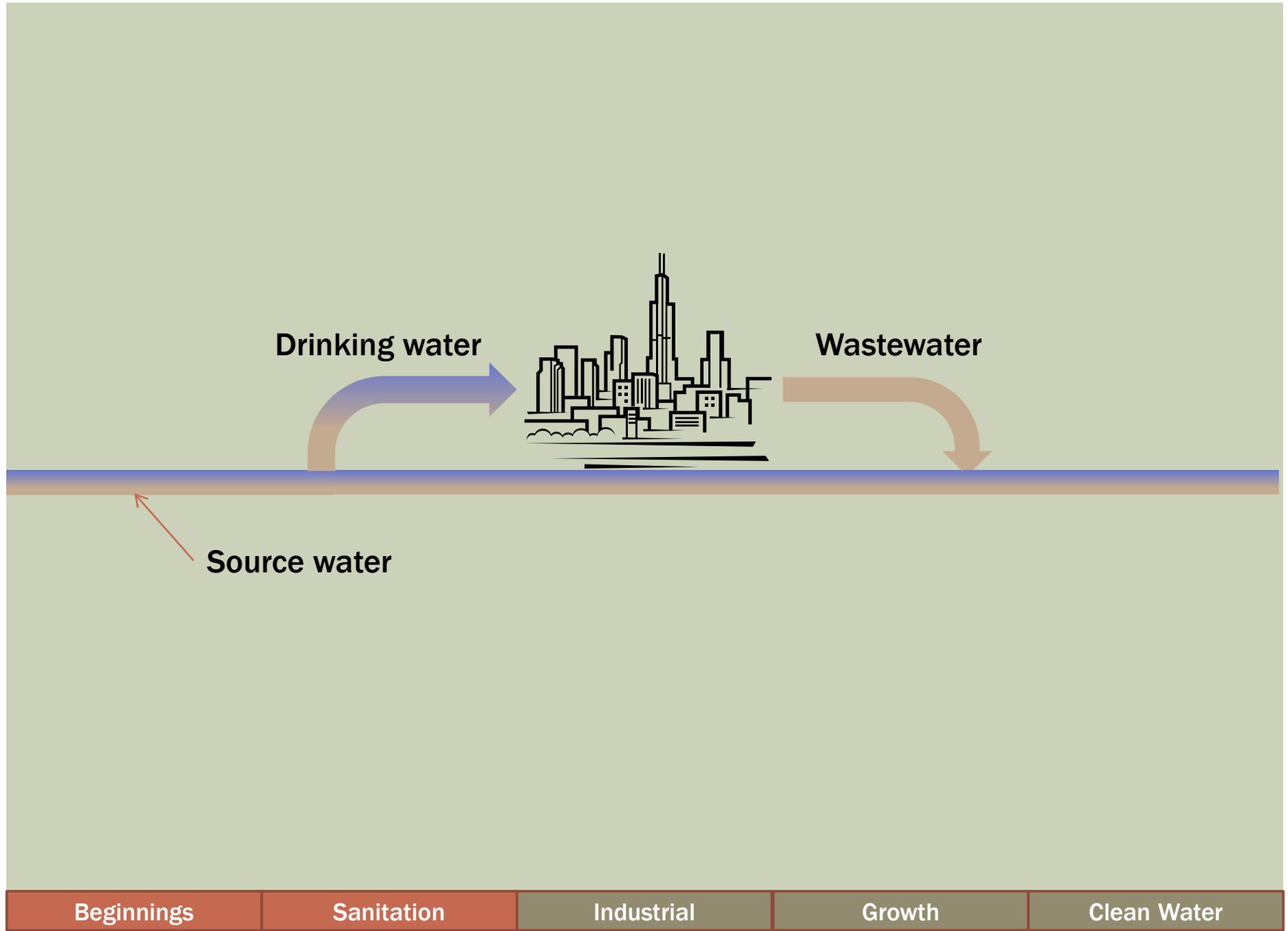
Beginnings

Sanitation

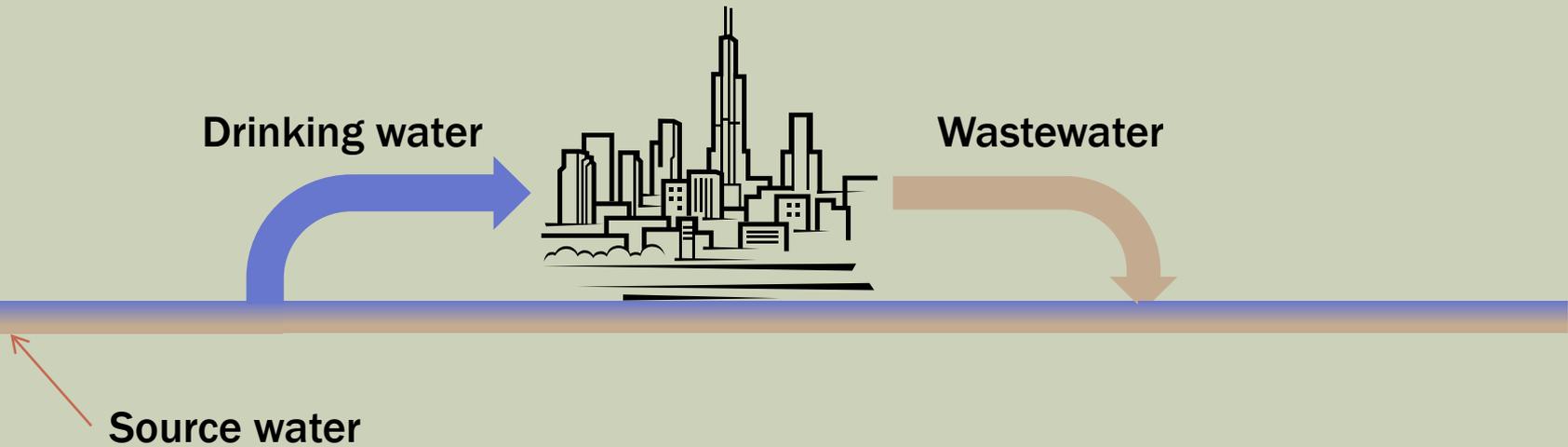
Industrial

Growth

Clean Water



THE WATER SANITATION ERA



Beginnings

Sanitation

Industrial

Growth

Clean Water

UNITED STATES PUBLIC HEALTH SERVICE

RUPERT BLUE, SURGEON GENERAL

**STUDIES ON THE SELF-PURIFICATION
OF STREAMS**

BY

EARLE B. PHELPS

*Professor of Chemistry, Hygienic Laboratory
United States Public Health Service*

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AUGUST 14, 1914



WASHINGTON
GOVERNMENT PRINTING OFFICE

1914

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Beginnings

Sanitation

Industrial

Growth

Clean Water

THE WATER SANITATION ERA

TABLE 7.

Typhoid Death Rates at Cincinnati and Louisville Before and After Introducing Filtration.

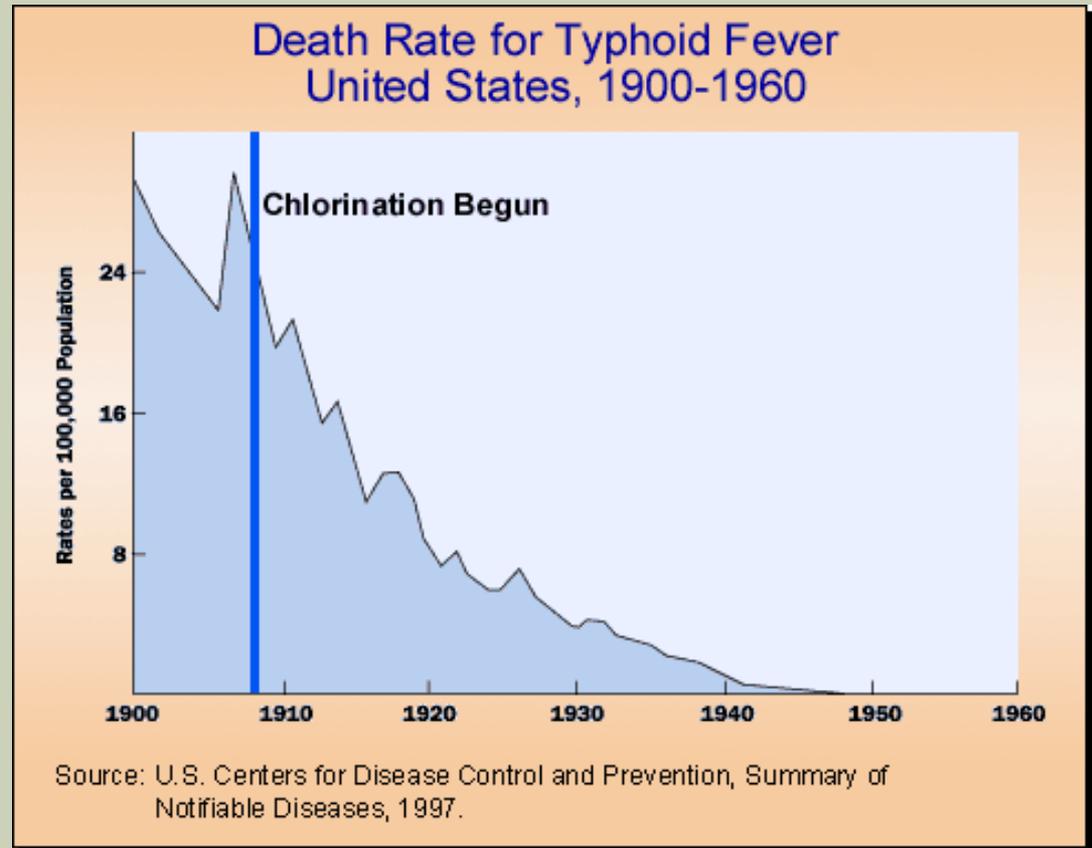
Crry.	Rate Per 100,000.	Remarks.
Cincinnati.....	64.0	Average for three years, 1904, 1905, and 1906, before using filtered water.
Cincinnati.....	12.6	Average for three years, 1908, 1909 and 1910, after using filtered water.
Louisville*.....	53.6	Average for two years, 1907 and 1908, before using filtered water.
Louisville*.....	35.8	Rate for 1909, filter plant in operation one-half year.
Louisville*.....	24.2	Average for two years 1910 and 1911, after using filtered water.

*Estimated population.

Indiana State Board of Health, 1911

THE WATER SANITATION ERA

- Coagulation
- Filtration
- Chlorination



Beginnings

Sanitation

Industrial

Growth

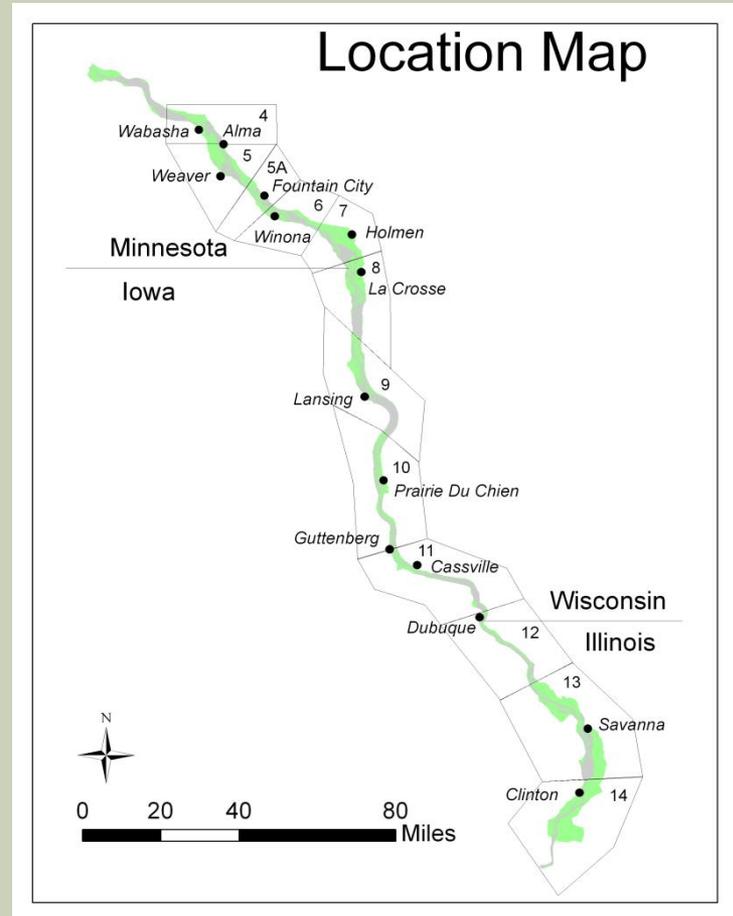
Clean Water

BEYOND SANITATION

PERCEPTIONS: Recognition of the regional nature of water quality problems (Public Health Service Act of 1912).

ECOLOGY: Fish service attributes demise of freshwater mussel to silt originating from agricultural land clearing (1923).

CHANGES: Izaak Walton League cites increased flooding and sediment problems in its argument for creating Upper Mississippi River Fish and Wildlife Refuge (1924).



POLLUTION PROBLEMS WORSEN

OIL: Internal combustion engines became popular and lead to more frequent oil spills in US rivers.

BOD: Low oxygen and/or high ammonium plagues US rivers as organic inputs increase.

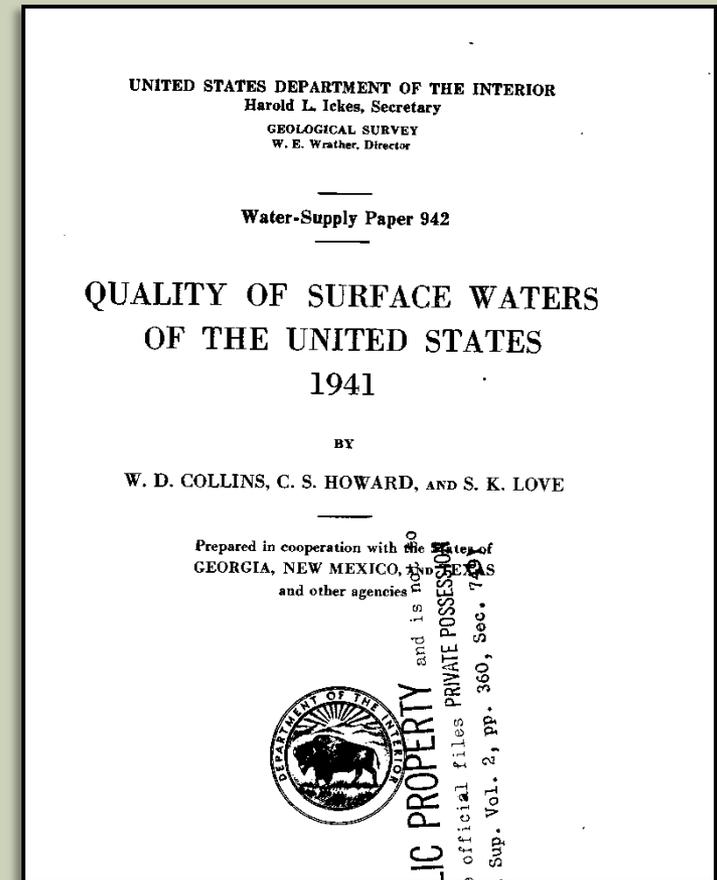
NAVIGATION: Upper Mississippi River pollution exacerbated by navigational structures (Rivers and Harbors Act of 1930).



Navigational dam on the Mississippi River
(courtesy Mark Dornblaser)

THE NEW POLLUTION: INDUSTRIAL WASTE (1935-1948)

- Industrial production led to wastewater with new and exotic chemicals.
- US involvement in World War II outweighed concerns over improving water quality.
- US Public Health Service issued guidelines for maximum allowable concentration of mercury and several other toxic pollutants (1942).
- Renewed interest in collecting and publishing water quality data.



Beginnings

Sanitation

Industrial

Growth

Clean Water

THE RISE OF INDUSTRIAL WASTE (1935-1948)

Water Pollution Control Act of 1948

- First Federal law dealing with water quality.
- Estimated that more than 100 similar bills were defeated 1902-1948.
- Allowed the Surgeon General to sue states which polluted a water body that crossed state boundaries.
 - Required the state's consent!
 - Focused on impaired water usage for downstream states.



The Growth Era (1948- 1972)

Beginnings

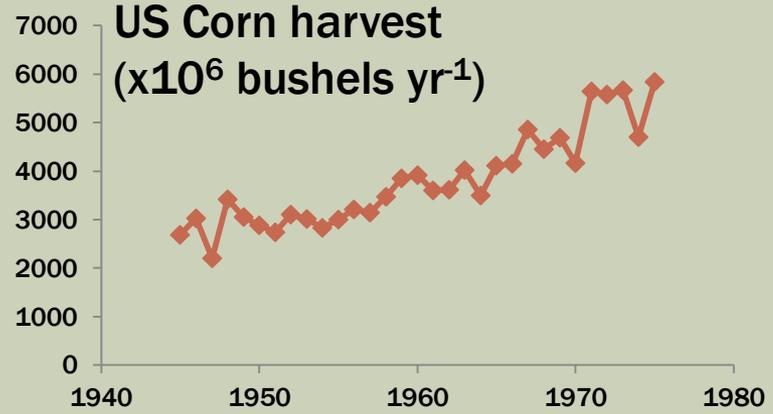
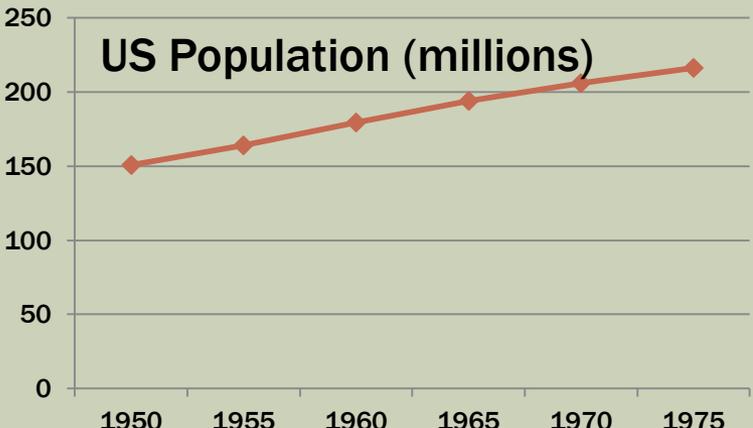
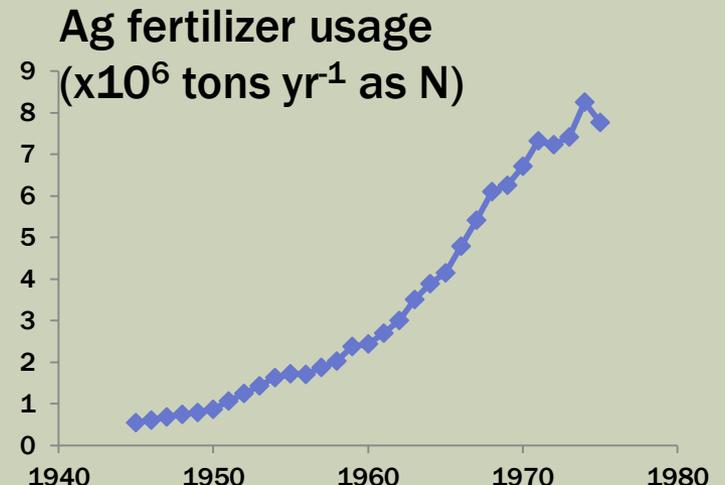
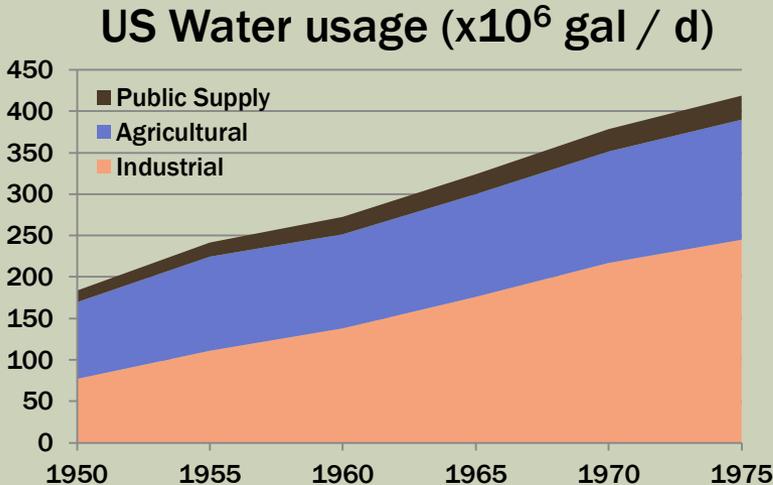
Sanitation

Industrial

Growth

Clean Water

MIDDLE 20TH CENTURY GROWTH IN THE US



EMERGENT WATER QUALITY PROBLEMS IN THE MID 20TH CENTURY

Eutrophication

- Not well understood.
- Richard Vollenweider credited with making the link to nutrients (late 1960s).

Aging water treatment facilities

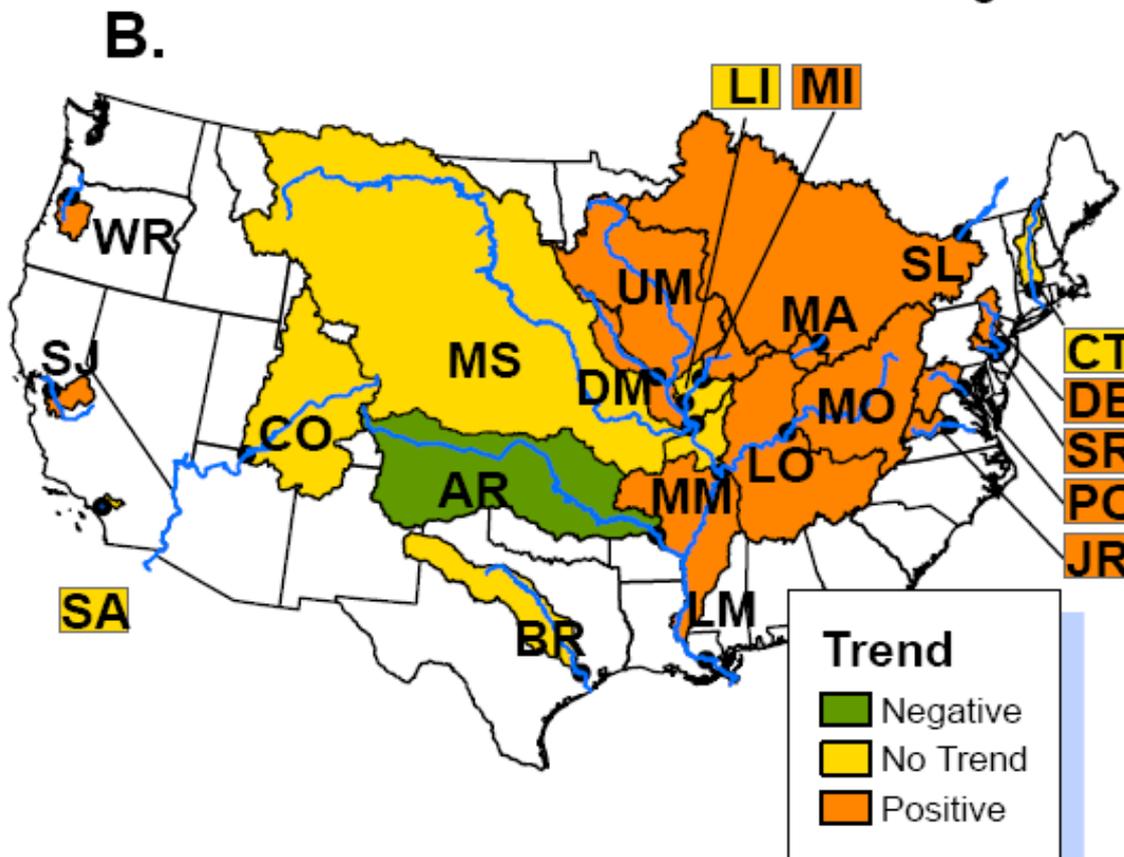
- Most facilities built in 1920s and 1930s.
- Reached design age by the 1950s.
 - Provided impetus to upgrade many facilities.

Water shortages begin to develop

- Partially due to pollution problems.
- New laws often focused on protecting water quality as a way of increasing supply.

NITRATE TRENDS 1945-1980

Figure 2.

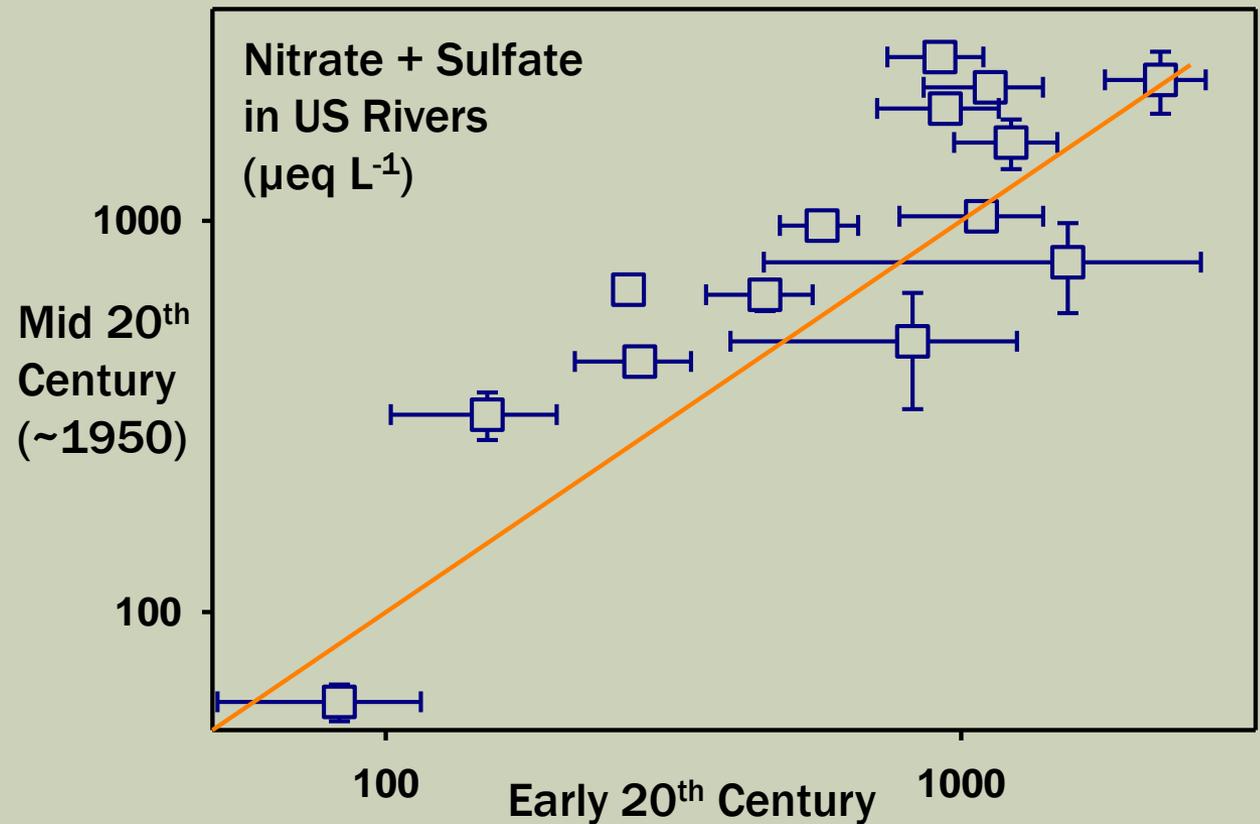


Negative	1
No Trend	7
Positive	14

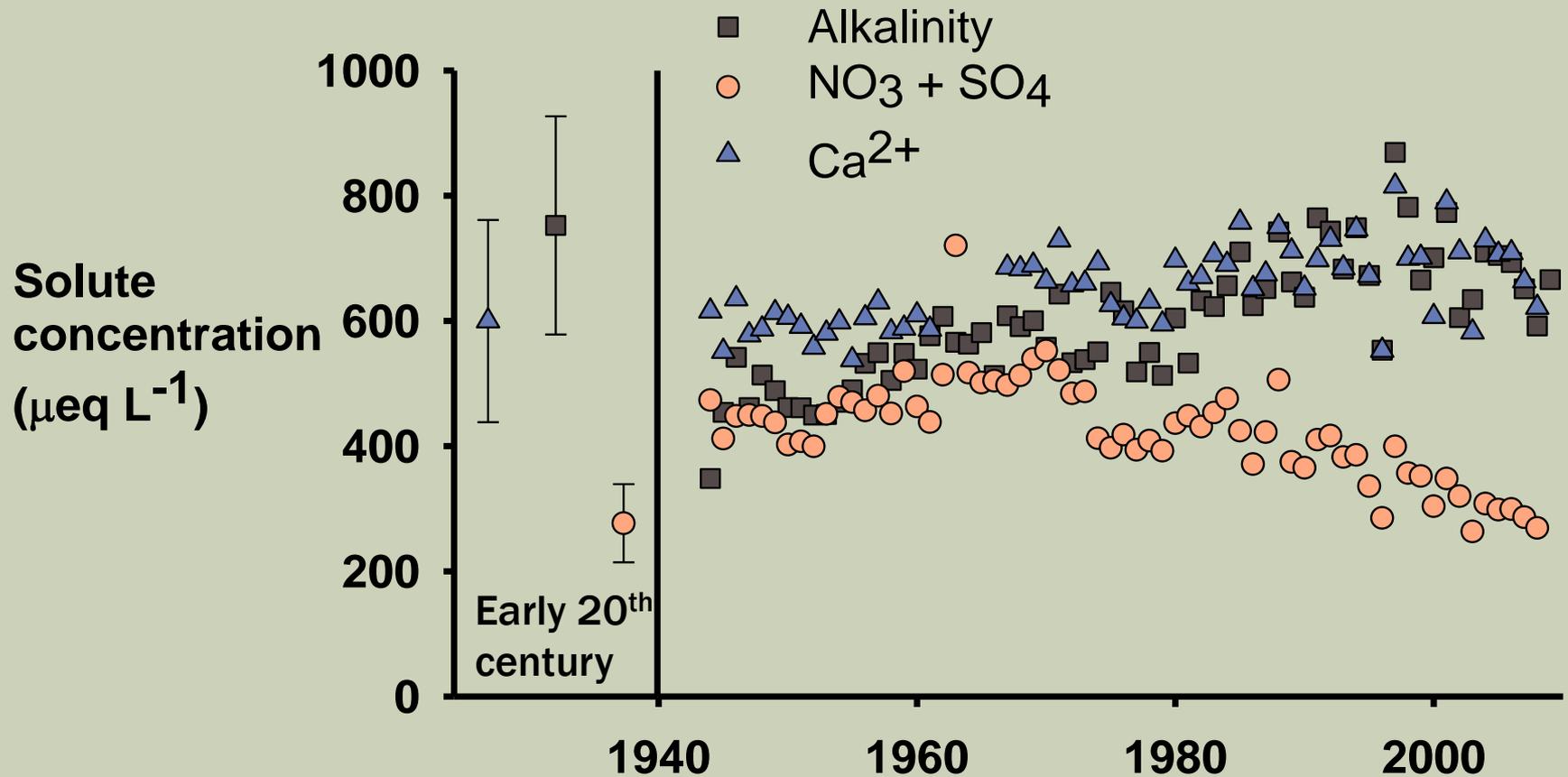
ACIDIFICATION OF US RIVERS IN THE MID-20TH CENTURY

Nitrate + sulfate concentrations were elevated in many US rivers by the middle of the 20th century.

Indicative of acidification.



MID-20TH CENTURY ACIDIFICATION AND SUBSEQUENT RECOVERY



Delaware River at Trenton, NJ

A DESCRIPTION OF THE POLLUTION

- The number of fish killed from pollution grew from 6 million in 1960 to 41 million in 1969.
- Shrimp harvest in 1965 was 0.2 percent of that in 1936.
- More than 90 percent of basins studied were considered polluted.

Second Annual Report of the President's Council on Environmental Quality, 1971.

POLICY RESPONSES

- **Water Pollution Control Act (1948) → Largely ineffective.**
- **Updates in 1956**
 - **Grant system for wastewater treatment plant construction.**
 - **Allowed federal support for state projects to improve water quality.**
 - **Permitted projects to consider “propagation of fish, aquatic life, and wildlife.”**
- **Water Quality Act 1965**
 - **Required states to set pollution standards.**
 - **Created Federal Water Pollution Control Administration.**
 - **Attempted to preserve state supremacy in dealing with water quality.**
 - **Regulatory environment was ambiguous.**
- **Clean Water Act 1972**

WATER POLLUTION CONTROL ACT OF 1972 (CLEAN WATER ACT)

- Stated goal is to “restore and maintain the chemical, physical, and biological integrity of the Nation’s waters”.
- Begins with the premise that US waters ought to be free from pollution.
- Requires justification of pollution through NPDES permitting system.
- Required improved wastewater treatment by municipalities.
- Recognizes water pollution from both point sources and nonpoint sources.
- Exceptions for storm water and agricultural runoff.



Robert Hite Wastewater Treatment Facility



Farm fields near Fort Dodge, IA

TIMELINE OF RECENT WATER QUALITY POLICY

1977 – Rural Clean Water program added to support agricultural best management practices.

1987 – Clean Water Act Reauthorization

- NPDES requirements extended to municipal stormwater.
- State block grants for clean water were eliminated.
- State Clean Water Revolving Fund initiated.
- Support for nonpoint source pollution abatement established (section 319*h*)

TIMELINE OF RECENT WATER QUALITY POLICY

2001 – Solid Waste Authority of Northern Cook County v. U.S. Army Corps of Engineers

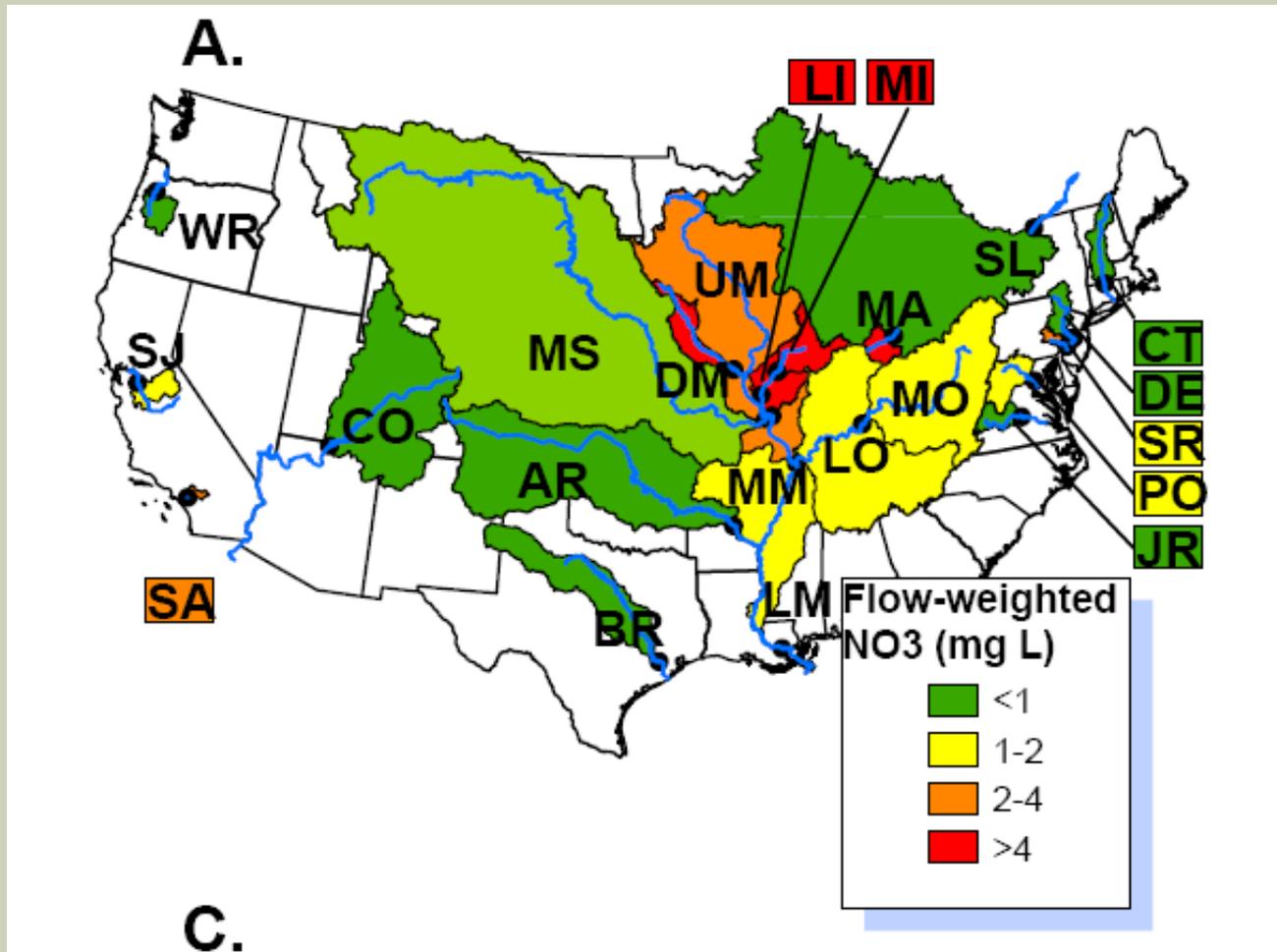
2006 – Rapanos v. United States

2015 – Clean Water Rule

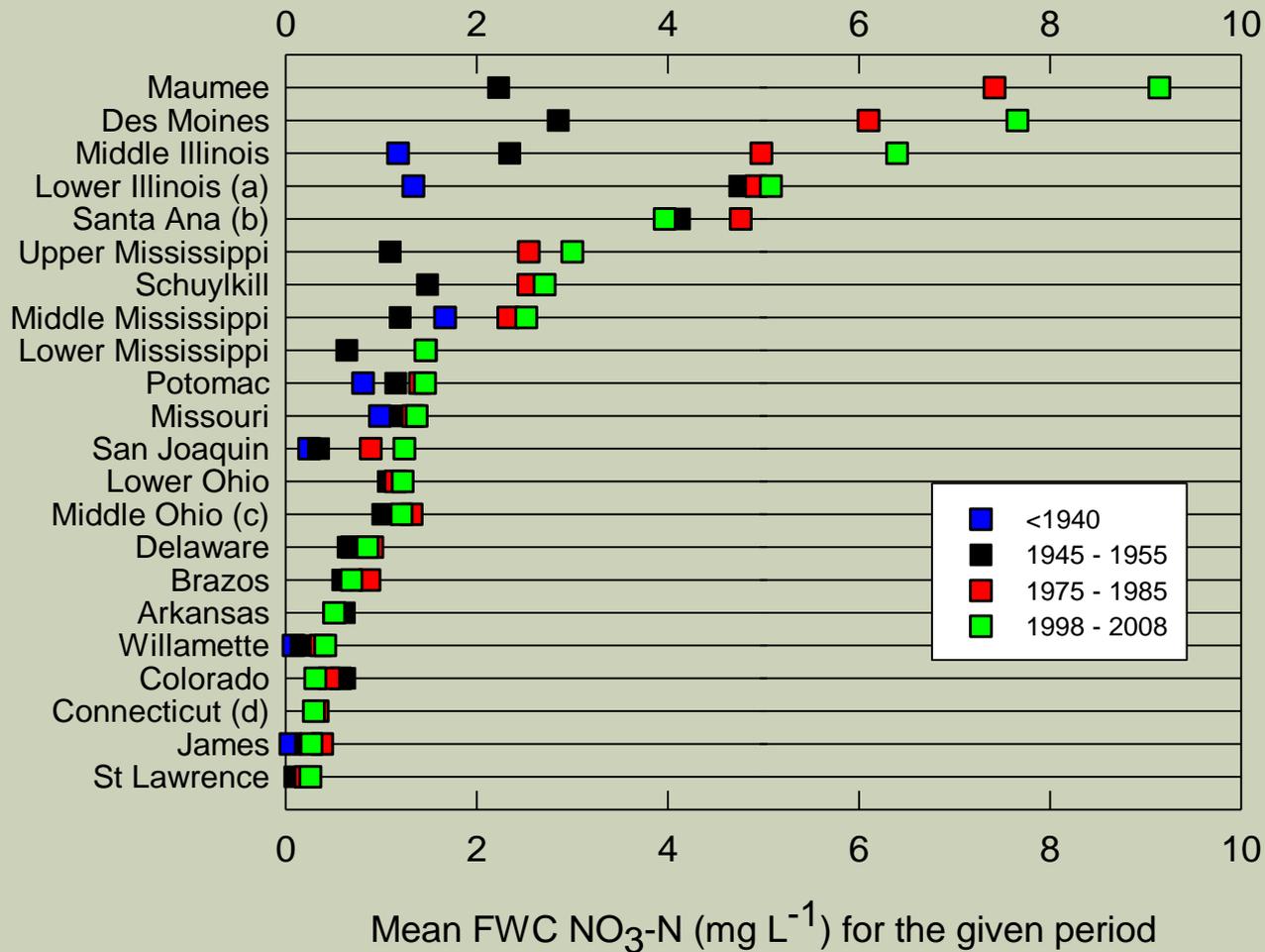
- Clarified statutory authority of EPA under the Clean Water Act.
- EPA authorized to regulate flowing waters.
- Waters in 100 year flood-plain (up to 1500 feet from flowing waters).
- Estimated to cover ~ 60 percent of surface freshwaters in U.S.

**RECENT LEVELING OF
MID-20TH CENTURY
NITRATE INCREASES IN
US RIVERS**

PRESENT-DAY SPATIAL PATTERNS

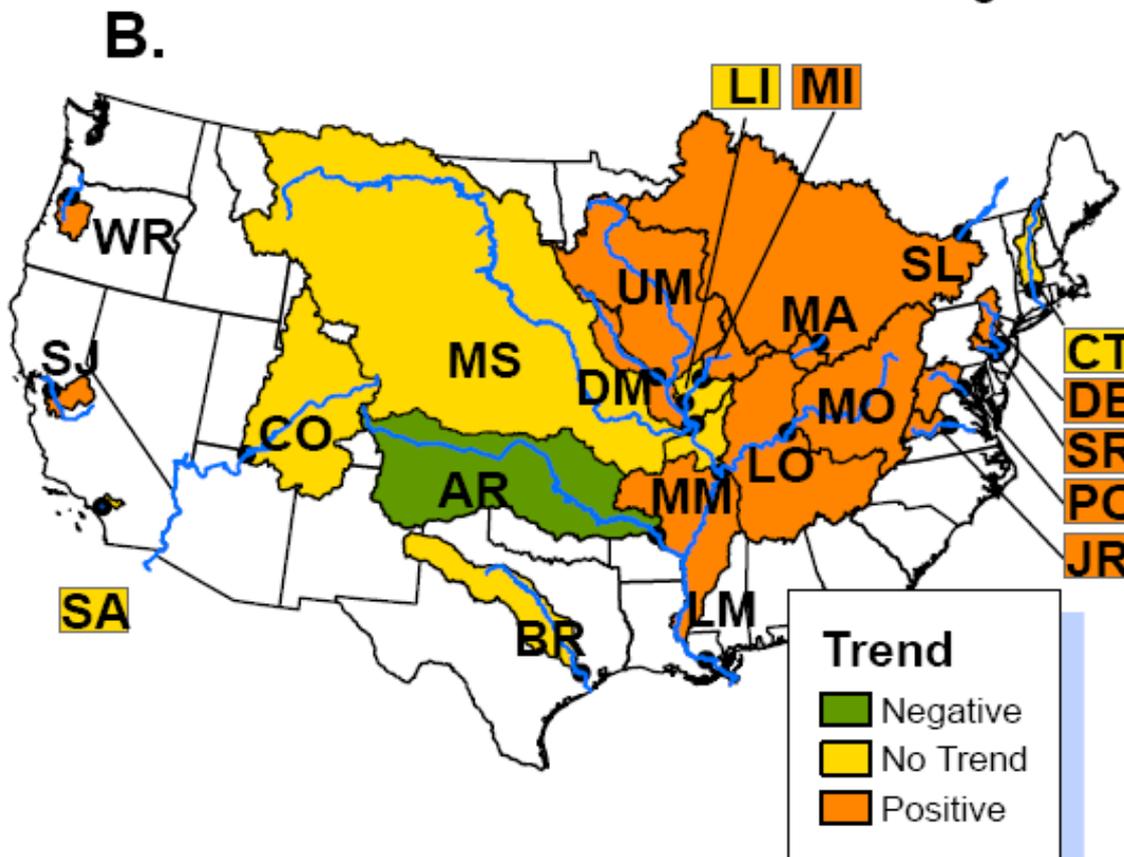


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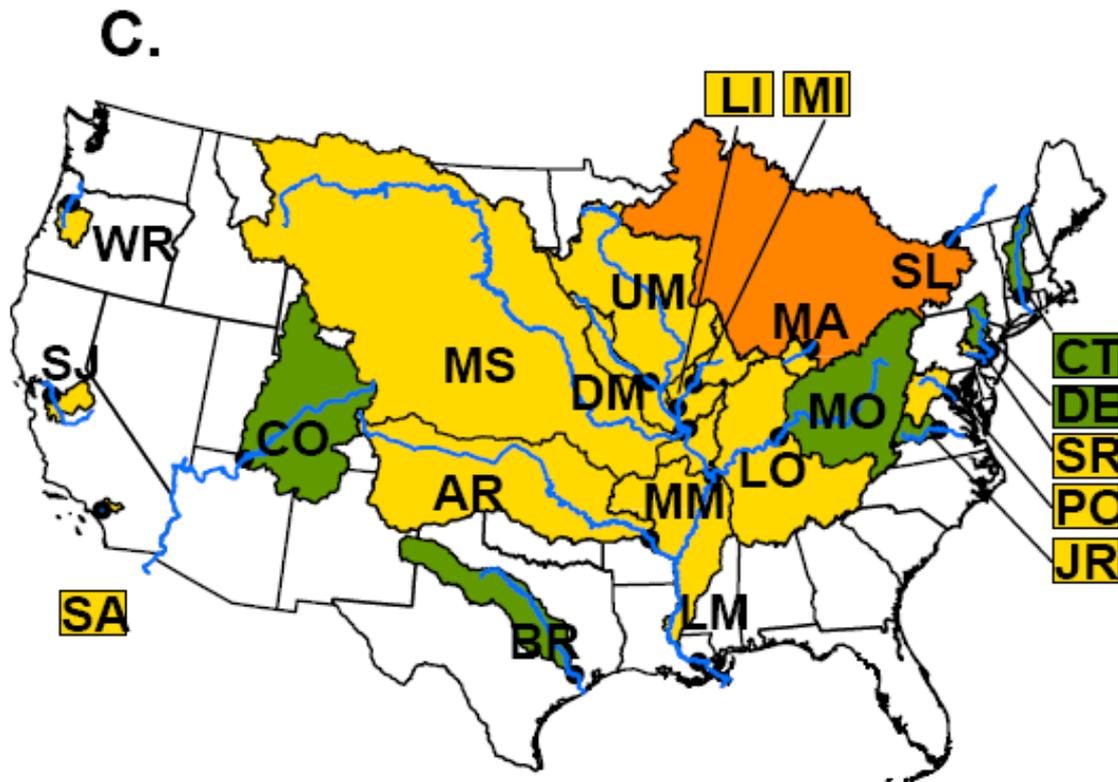
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Figure 2.



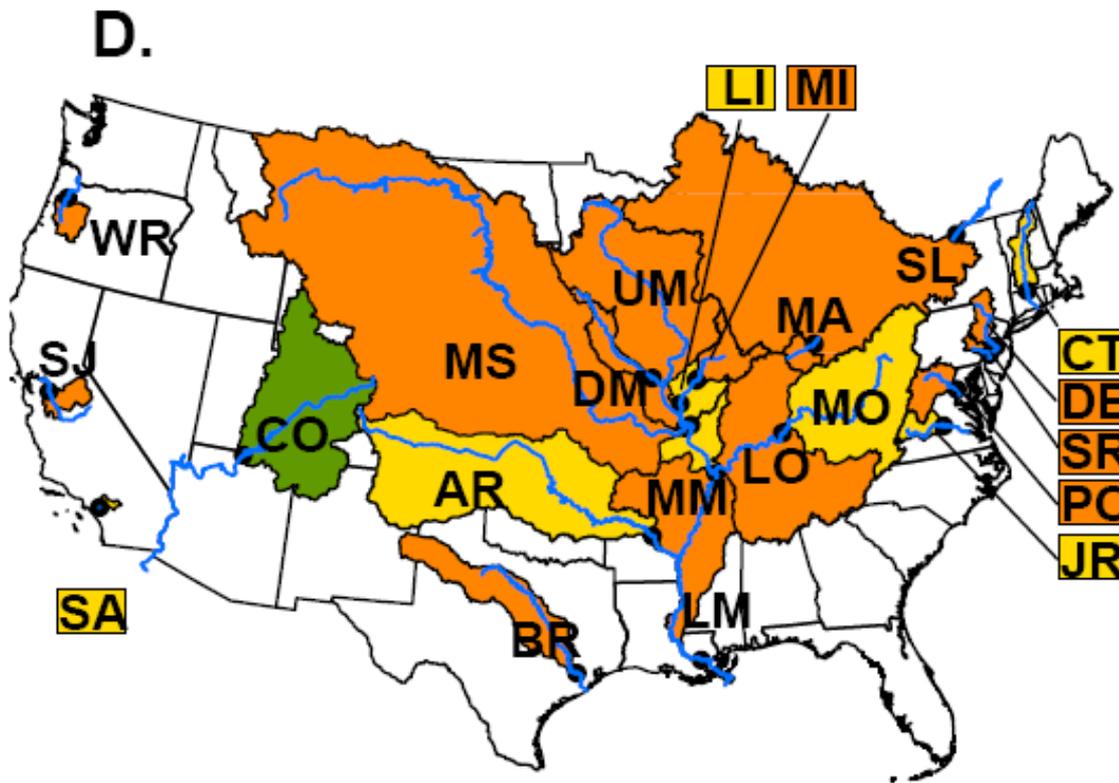
Negative	1
No Trend	7
Positive	14

NITRATE TRENDS 1981-2008



Negative	6
No Trend	15
Positive	1

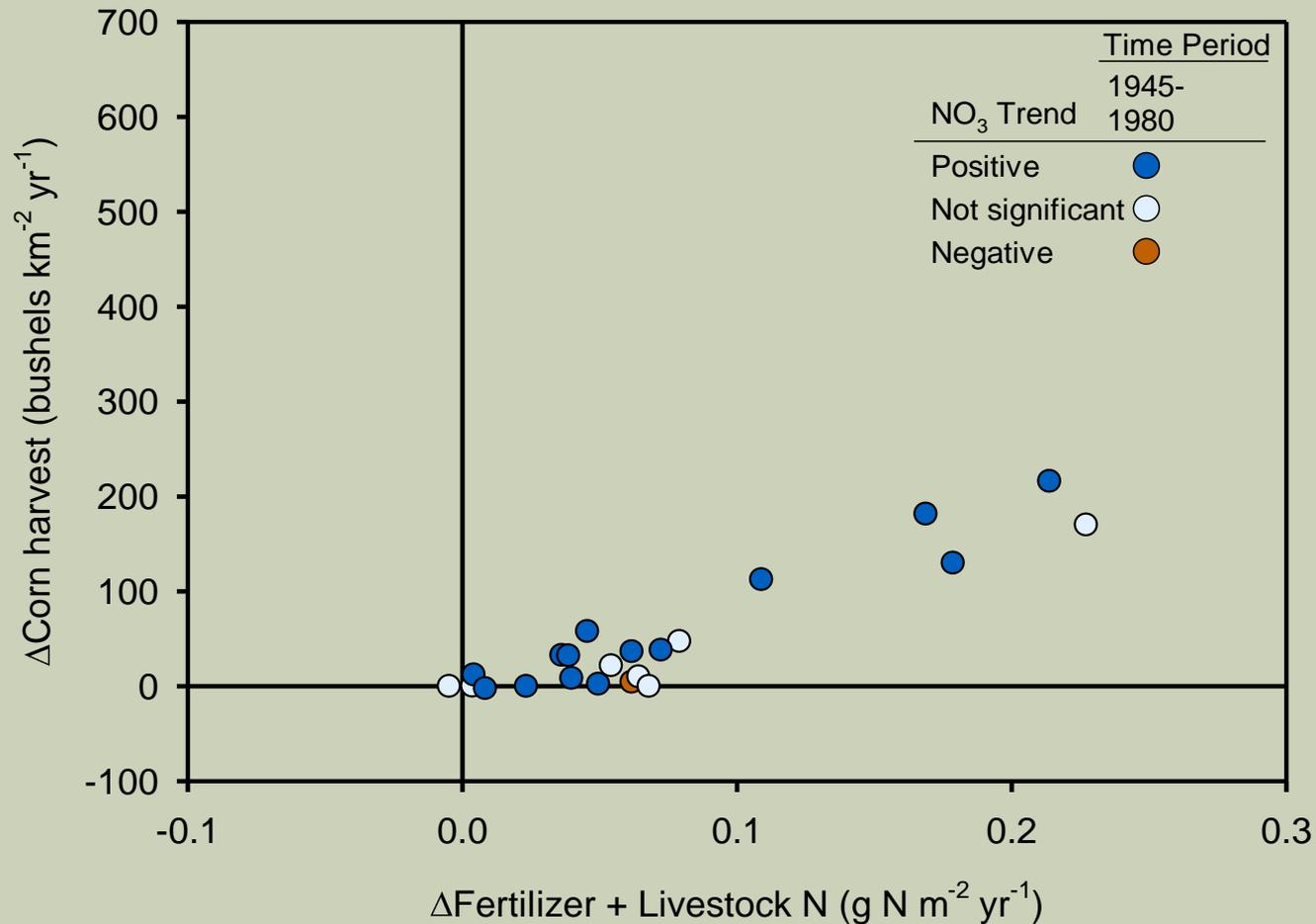
NITRATE TRENDS 1945-2008



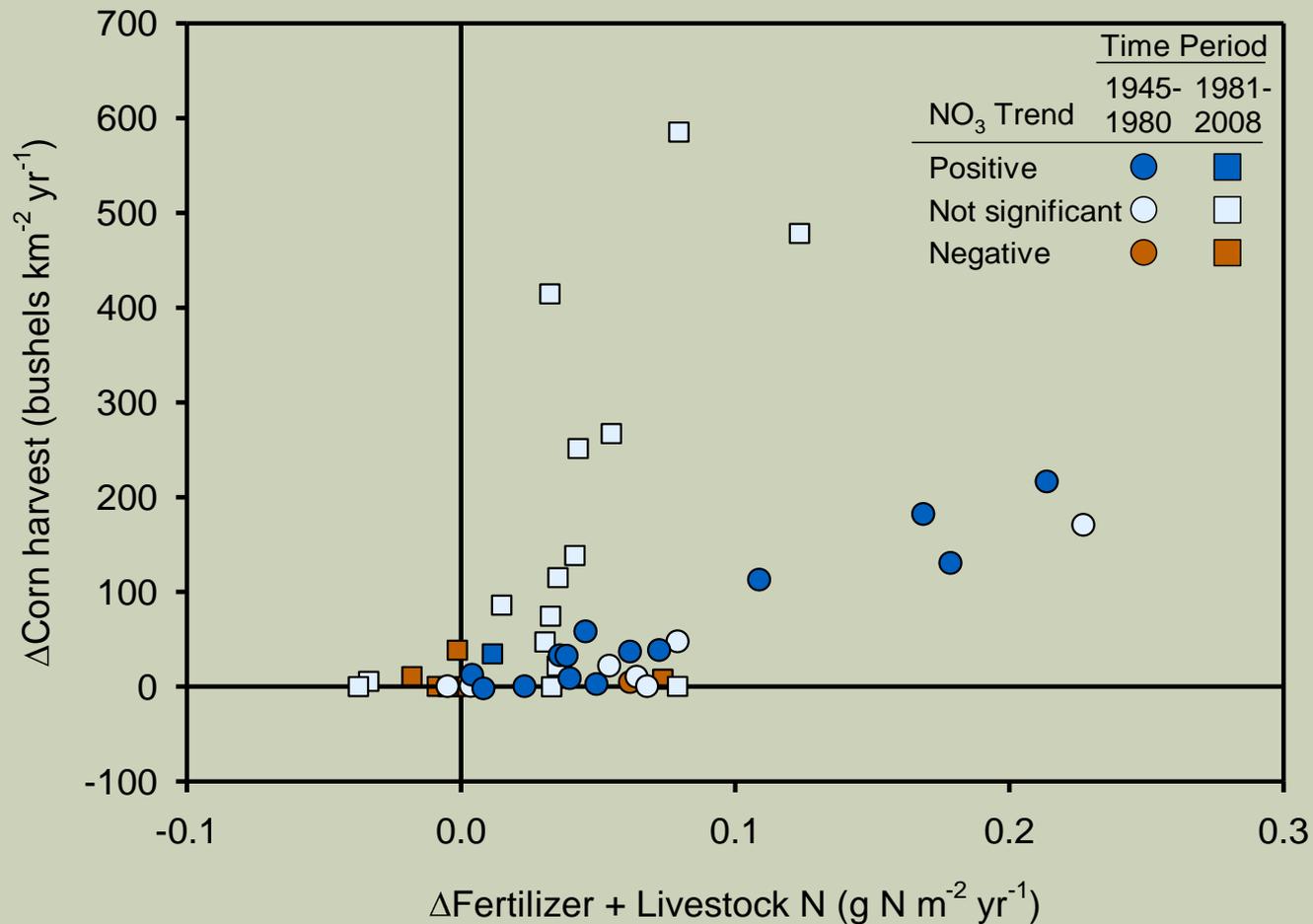
Negative	1
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Positive	14

Positive trends during 1945-1980 associated with overall (1945-2008) positive trends ($X^2 = 5.33$, $P = 0.02$)

INCREASED N INPUTS RELATED TO INCREASED AGRICULTURAL PRODUCTION



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Problems and progress (1987-present)



CENTURY OF TRENDS PUBLICATIONS

Stets, E. G., V. J. Kelly, W. Broussard, T. E. Smith, and C. G. Crawford (2012), Century-scale perspective on water quality in selected river basins of the conterminous United States. *U.S. Geological Survey Scientific Investigations Report 2012-5225*, 120 p.

Stets, E. G., V. J. Kelly, and C. G. Crawford (2014), Long-term trends in alkalinity in large rivers of the conterminous US in relation to acidification, agriculture, and hydrologic modification, *Science of The Total Environment*, vol. 488, pp. 280-289.

Kelly, V., E. G. Stets, and C. Crawford (2015), Long-term changes in nitrate conditions over the 20th century in two Midwestern Corn Belt streams, *Journal of Hydrology*, vol. 525, pp. 559-571.

Stets, E. G., V. J. Kelly, and C. G. Crawford (2015), Regional and Temporal Differences in Nitrate Trends Discerned from Long-Term Water Quality Monitoring Data, *JAWRA Journal of the American Water Resources Association*, vol. 51 (5), pp. 1394-1407.

<https://profile.usgs.gov/estets>

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